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CHEMICAL CHANGES IN STORED GRAINS
A Selected and Annotated Bibliography[1]

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1. Babbitt, J. D. Hysteresis in the adsorption of water vapor by wheat. Nature 156: 265-266. 1945.

   It is not possible to bring dried wheat back to its original wet moisture content, because of hysteresis.

2. _____ The thermal properties of wheat in bulk. Canad. Jour. Res. Sect. F., 23 (6): 388-401. 1945.

3. Bakke, A. O., and Stiles, H. Thermal conductivity of stored oats with different moisture content. Plant Physiol. 10: 521. 1935.

4. Barton-Wright, E. C., and Tompkins, R. G. The moisture content and growth of mold in flour, bran, and middlings. Cereal Chem. 17: 332. 1940.

5. Blanc, A. Essais de conservation de blé in atmosphere confinée. Compte rendues des séances de l'Academie d'Agriculture de France 24 (18): Supplement à la séance du 8 juin 1938.

6. Carter, Edward P., and Young, George Y. Effect of moisture content, temperature, and length of storage in the development of "sick" wheat in sealed containers. Cereal Chem. 22: 418-428. 1945.

   "'Sick' wheat was produced artificially by storing sound wheat containing different amounts of moisture in sealed quart Mason jars at various temperatures in temperature-controlled cabinets, the proportion of 'sick' kernels in general increasing with the moisture content of the grain, the temperature of storage, and the length of the storage period. There was little fungus growth on the wheat

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1/ This is an interim, non-exhaustive addition to the bibliography on Chemical Changes in Stored Grains, processed publication by Carol M. Jaeger, Northern Regional Research Laboratory, Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture, March 1943.

such as usually takes place when moist wheat is exposed in the open air, except in a few jars and these were discarded.

"Wheat containing 12.2 percent moisture stored at 40° C. developed 'sick' wheat symptoms when stored 279 days or longer, but not when stored at a lower temperature. A small percentage of 'sick' wheat was produced in 32 days in wheat containing 18.6 percent moisture when stored at 5° C. and up to 100 percent 'sick' kernels when stored at higher temperatures and for longer periods of time. The development of the 'sick' wheat condition in general was accompanied by loss in viability and increase in fat acidity."

7. Christenson, Clyde M., and Gordon, Dorothy R. The mold flora of stored wheat and corn and its relation to heating of moist grain. Cereal Chem. 25: 40-51. 1948.

"....The number of molds on corn increased with increasing moisture content of the seed. ....Autoclaved moist wheat inoculated with 200,000 spores of Aspergillus flavus per gram heated to 45° C. in 2 days, while that inoculated with only 0.2 spore per gram heated to a comparable temperature in 9 days, indicating that if conditions for mold growth are favorable, the amount of inoculum originally present may have only a minor effect on eventual heating. Under conditions of the tests, none of the several fungacides used eliminated molds from moist, stored wheat, and thiourea appeared to be less toxic to A. candidus than to other common molds."

8. DeLong, H. H. Safe storage for grain sorghums. S. Dak. Agr. Eng. Pamphlet No. 3 (Rev.) Aug. 1945.

Progress report on the six methods of sorghum grain storage now being investigated at South Dakota. (Nothing on chemical changes.)

9. Dexter, S. T., and Creighton, J. W. A method for curing farm products by the use of drying agents. Jour. Amer. Soc. Agron. 40 (1): 70-79. 1948.

"Blocks of wood or other porous material impregnated with a suitable proportion of calcium chloride, magnesium chloride, or other desiccant have been found effective in removing moisture from the interstitial atmosphere, and thus from hay or grain in mows or bins. With this method of reducing the relative humidity in the storage space, spoilage was prevented. Blocks may be so prepared that they will readily absorb from 50 to 100 percent or more of their dry weight."

10. Hutchinson, J. B., and Booth, R. G. The drying of wheat. IV Phosphatase activity as an index of heat damage in cereals. Jour. Soc. Chem. Indus. Trans. 65 (8): 236-237. 1946.

"The baking quality, germination vitality, and phosphatase activity of a wheat were examined after heat treatment at moisture contents ranging from 5.5 to 35 percent. Curves relating the percentage of phosphatase inactivation to temperature of treatment are presented. The correlation between phosphatase inactivation and damage to either vitality or baking quality varies with moisture content and is less than that between vitality and baking quality in the important region above 15 percent moisture. The detection and use of an enzyme system of greater heat lability than phosphatase is desirable for the unequivocal diagnosis of mold damage to either vitality or baking quality of wheat."

11. _____ Greer, E. N., and Thomas, P. T. Heat damage in cereal grains. Nature 158 (4004): 120-121. 1946.

A cytological study, mainly, and a comparison with burn damage of animal tissues.

12. James, Norman, Wilson, Joyce, and Stark, Egon. The microflora of stored wheat. Canad. Jour. Res., Sect. C., 24 (5): 224-233. 1946.

Wheat passing through the Winnipeg market in 1943 and 1945 harboured a large number of microorganisms. It is suggested that these species should be considered epiphytic on wheat.

13. Karon, M. L., and Altschul, A. M. Respiration of cottonseed. Plant Physiol. 21 (4): 506-521. 1946.

14. Kretovich, V. L. Physiologico-biochemical bases for the storage of grain. Akad. Nauk. U. S. S. R., Inst. Biokhim., Moscow-Leningrad. 1945, 136 pp. (Separate); translation at USDA Library, Washington, D. C., Chem. Abs. 40 (5): 1237[8]. 1946.

Many analyses are given showing the biochemistry of grain ripening, and summaries of experiments are given on the most beneficial ways of treating wheat for storage.

15. Kyame, Lillian, and Altschul, A. M. Comparison of respiration, free fatty acid formation, and changes in the spectrum of the seed oil during the storage of cottonseed. Plant Physiol. 21 (4): 550-561. 1946

"That both respiration and lipolysis equally reflect the vigor of cotton seeds is a fact of great practical importance in commercial storage. On the basis of this fact it would be reasonable to predict that seeds whose respiration intensity is high--that is, seeds that heat readily when stored in bulk would, even when heating is controlled by air circulation, undergo more intensive lipolysis than seeds of equal moisture content but lower respiratory activity. Thus, the measurement of the heat resulting from respiration should be a useful criterion in predicting the storage behavior of seeds.

"The behavior of immature seeds is entirely different from that exhibited by mature seeds. In immature seeds, the enzyme systems have not reached the state of dormancy which characterizes them in mature seeds. For this reason, immature seeds are more sensitive to moisture and respire at a higher intensity than do mature seeds. ....In effect, then, the maturation process which is interrupted by early harvesting of the cotton, is continued during storage."

16. Lewis, S. E., and Eccleston, K. Residues in wheat flour fumigated with methyl bromide. Jour. Soc. Chem. Indus. 65 (5): 149-152. 1946.

17. Longwell, J. H. Effect of storage on the feed value of hard red spring wheat. N. Dak. Bimonthly Bul. v. 7, No. 6, pp. 3-6. 1945.

Wheat from the 1940 crop was placed in the Commodity Credit Corporation storage bins in the summer of 1941. Examination of the wheat in the spring of 1944 gave the following results: (a) There were differences in moisture, test-weight, total nitrogen, and germination; and (b) no differences in feeding value for fattening pigs were found.

18. McCalla, A. G., and Newton, W. Effect of frost on wheat at progressive stages of maturity. II Composition and biochemical properties of grain and flour. Canad. Jour. Res., Sect. C., 13 (1): 1-31. 1935. III Milling and baking quality. Ibid Sect. C., 13 (5): 263-282. 1935.

19. Milner, Max, and Geddes, W. F. Grain storage studies. I Influence of localized heating of soybeans on interseed air movements. Cereal Chem. 22: 477-483. 1945; II The effect of aeration, temperature, and time on the respiration of soybeans containing excessive moisture. Cereal Chem. 22: 484-501. 1945; III The relation between moisture content, mold growth, and respiration of soybeans. Cereal Chem. 23: 225-247. 1946.

20. _____ Utility of sulfa drugs for the inhibition of mold respiration in grain. Science 104 (2707): 463-464. 1946.

"It is significant that the respiratory rate of the control sample on the first day, before mold proliferation commenced, was the same as that of samples treated with sulfanilamide. This respiratory rate (about 33 mg. CO_2/100 g. dry matter/day) remained virtually constant for 8 days at the highest concentration of sulfanilamide and is probably representative of the true seed respiration under the conditions of moisture and temperature applied. Germination data indicate that suppression of mold growth by sulfanilamide yielded a larger percentage of viable seeds at the end of the trial."

21. _____ Christensen, Clyde M., and Geddes, W. F. Grain storage studies. V Chemical and microbiological studies on "sick" wheat. Cereal Chem. 24 (1): 23-38. 1947.

The effects of molds and bacteria on wheats and relation to "sick" wheat are discussed. In addition to kernel studies, work on milled samples gave the following results:

"Fat acidity of mill fractions of sound wheat was at a maximum in the bran fraction, and decreased regularly toward the patent flour more or less in the order of the total fat content of the various fractions. The mill fractions of 'sick' wheat, on the other hand, showed highest fat acidity in the low-grade flour. The high lipase activity of the aleurone layer and scutellum, relative to that of the germ, is apparently responsible for this effect.

"More information is needed on the location, distribution, and activity of inherent wheat enzymes, such as the lipases and oxidizing enzymes, to explain the formation of fat acidity and the darkening of 'sick' wheat."

22. _____ Christenson, Clyde M., and Geddes, W. F. Grain storage studies. VI Wheat respiration in relation to moisture content, mold growth, chemical deterioration, and heating. Cereal Chem. 24 (3): 182-199. 1947.

23. _____ Christenson, Clyde M., and Geddes, W. F. Grain storage studies. VII Influence of certain mold inhibitors on respiration of moist wheat. Cereal Chem. 24 (6): 507-517. 1947.

"More than 100 compounds were tested for fungistatic ability on wheat stored with a moisture content of 16 to 25 percent. Few of these effectively inhibited the growth of molds on or in the seed. Some compounds inhibited certain molds but not others, or inhibited the surface growth and spore production of certain molds without preventing the growth of the molds in the interior of the seed. This suggests that the effectiveness of the given compound in inhibiting the development of molds on or in moist stored seed of any kind can be ascertained only by determining the number and kinds of molds originally present, and their subsequent increase or decrease after the seed has been treated with the supposed fungicide. ...."

24. Morey, Loran, Kilmer, Helen, and Selman, Roland W. Relationship between moisture content of flour and humidity of air. Cereal Chem. 24 (5): 364-371. 1947.

"The equilibrium moisture contents of a typical Kansas flour in contact with air of varying moisture content at 50°, 75°, and 95° C. were determined. A linear relationship exists between flour moisture content and the absolute humidity of the air. For a moisture content of 14 percent, the reciprocal of the absolute temperature is a linear function of the logarithm of the water vapor pressure. The heat of dehydration has been calculated as 10.7 calories per mole of water."

25. Nagel, C. M., and Semeniuk, G. Some mold-induced changes in shelled corn. Plant Physiol. 22 (1): 20-33. 1947.

"Shelled corn which molded during storage was found to be high in fat acidity and moisture percentage and low in bushel weight ....

"Pure cultures of nine fungi isolated from naturally molded corn were grown in the laboratory for a 4-week period on steam-sterilized corn initially adjusted to approximately 32 percentage moisture content....

"A positive linear relationship was found between the percentage loss in organic matter and the percentage of water (wet basis) in the moldy corn....

"Fat acidities in the corn were increased by all the fungi tested in this series of experiments...."

26. Robertson, D. W., Lute, A. M., and Kroeger, H. Germination of 20-year old wheat, oats, barley, corn, rye, sorghum, and soybeans. Jour. Amer. Soc. Agron., 35 (9): 786-795. 1943.

"Germination studies are reported on various farm crops stored for varying periods from 1 to 22 years.... A dry, arid climate preserves germination in the farm crops studies so that stock of wheat, oats, barley, sorghum, and corn can be stored for 20 years and still have enough viable seeds to maintain the stocks."

27. Sayre, J. D. Storage tests with seed corn. Farm and Home Research (Bimonthly Bul.) Ohio Agr. Expt. Sta. 32 (247): 149-154. 1947.

"Seed corn can be carried over for a number of years by drying it to 5 to 8 percent moisture content and storing it in air-tight containers at a low temperature, if possible, or in as low and as uniform a temperature as is available."

28. Scherwood, R. C. The influence of drying on quality of wheat. Min. Dept. of Agr. Bul. 66. 1929.

29. Schulerud, A. A study of the march of acidity in stored flours and some critical remarks on the methods used for the determination of flour acidity. Cereal Chem. 10 (2): 129-139. 1933.

30. Sharp, P. F., and Elmer, R. Wheat and flour studies. I Proteolytic enzymes of flour. I Auto-digestion of flour milled from frozen and non-frozen wheat harvested at various stages of maturity. Cereal Chem. 1 (2): 83-106. 1924.

"Protein fraction analysis of flour milled from wheat harvested at various stages of growth, as described, indicates no change in the glutenin, an increase in the gliadin, and a decrease in the 5 percent potassium sulphate-soluble and amino nitrogen as the kernel develops.

"Subjection of the immature wheat to freezing temperatures by the method described had no effect on the protein fractions as compared with the non-frozen wheat.

"The total protein of the flour milled from wheat harvested at various stages of maturity did not differ greatly although a slight decrease followed by an increase is indicated over the range studied.

"The proteolytic enzymes of wheat flour are capable of digesting the flour protein if given sufficient time in which to act.

"Auto-digestion of flour for a considerable period of time apparently produces no decrease in the glutenin, causes a decrease in the gliadin, and an increase in the 5 percent potassium sulphate-soluble and amino nitrogen fractions. The decrease in the gliadin fraction is not all accounted for by the increase in the potassium sulphate-soluble fraction but also shows up as an increase in the glutenin fraction.

"The decrease in the gliadin fraction is apparently independent of the stage of kernel development, but the percentage increase in the potassium sulphate-soluble fraction is greater in the more immature stages of growth.

"Freezing as carried out under these conditions apparently affects the proteolytic activity of the flours very little if at all."

31. _____ Wheat and flour studies. III The amino nitrogen content on the immature wheat kernel and the effect of freezing. Cereal Chem. 2 (1): 12-38. 1925; VII The composition of wheat and mill products from frozen and non-frozen wheat harvested at various stages of maturity. Cereal Chem. 3 (6): 402-410. 1926.

32. Simons, J. W. Drying seed grain with calcium chloride. Agr. Engin. 29 (3): 112-113. 1948.

Gives data on drying blue lupine seeds.

33. Smith, Luther. The effect of chaff of cereals on germination of seeds and on the growth of mold. Jour. Amer. Soc. Agron. 40 (1): 32-44. 1948.

34. Sreenivasan, A. Storage changes in rice after harvest. Indian Jour. Agr. Sci. 9 (Pt. 2): 208. 1939; Biochem. Zschr. 301: 210. 1939.

"With the natural moisture of approximately 13.5 percent the seed was dead after 5 months' storage at 30° C. and after 2 years at 20°. Full viability was kept for 3 years at 10°, but germination fell rapidly after that. Practically full germination was maintained for 10 years at 2° and full germination at -10°.

"Seed dried to 8 to 9 percent moisture showed little or no loss of germination when stored at 30° C. for 1 year, but the fall in germination was very rapid after 1 year. Seed stored at 20° germinated 90 percent after 5 years and lost viability gradually in subsequent years. The seed stored at 10°, 2°, and -10° did not change in germination in 10 years.

"Seed dried from approximately 13.5 to approximately 5 percent in 44 hours showed severe injury to germination when stored at low temperatures."

38. Whymper, R., and Bradley, A. A note on the viability of wheat seeds. Cereal Chem. 24 (3): 228-229. 1947.

The authors report a viability of 69 percent after 32 years of storage for some English wheats.

39. Winteringham, F. P. W., and Harrison, A. The sorption of methyl bromide by whole wheat. Jour. Soc. Chem. Indus. 65 (5): 140-149. 1946.

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